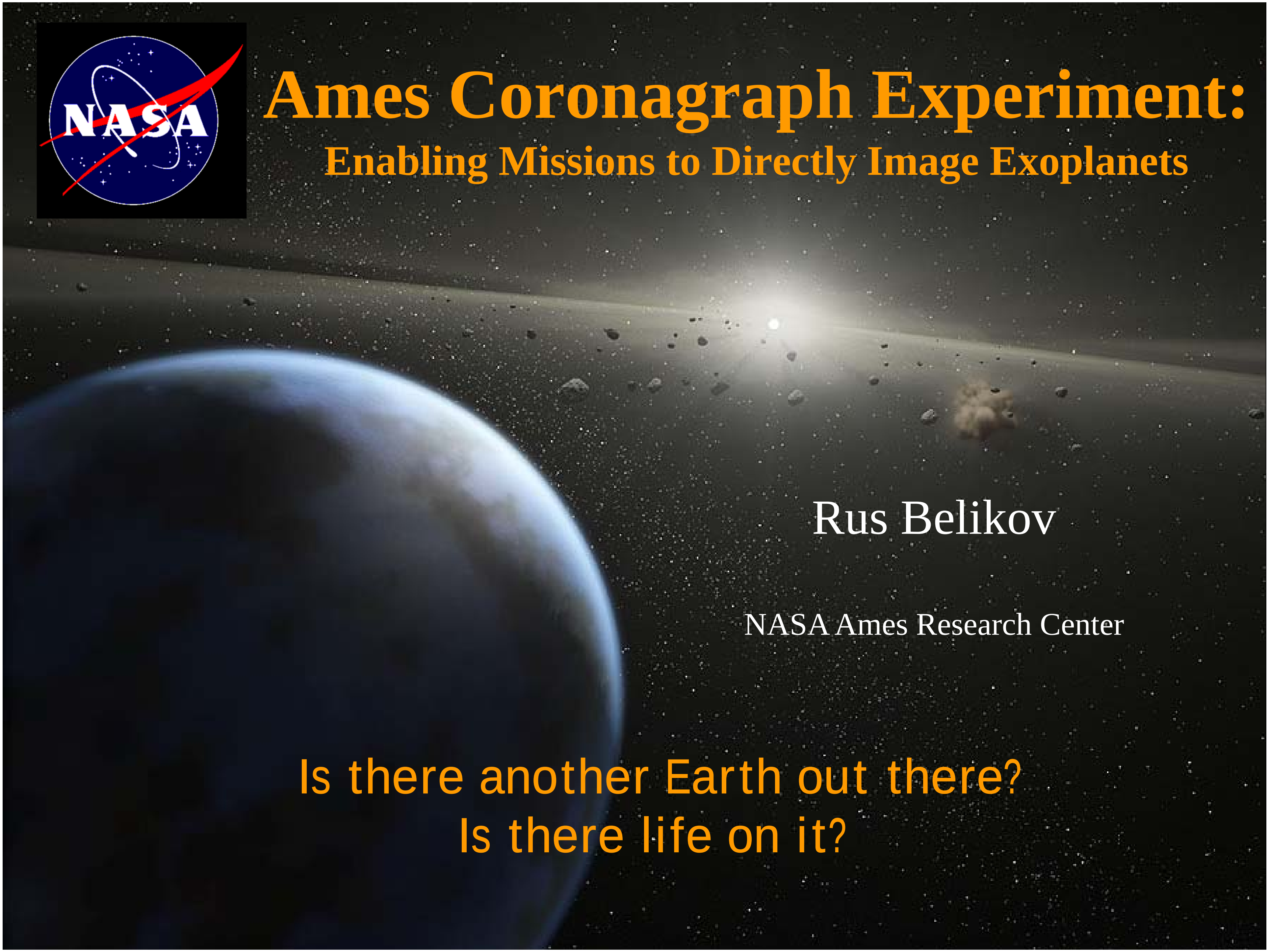


Ames Coronagraph Experiment:

Enabling Missions to Directly Image Exoplanets

Rus Belikov

NASA Ames Research Center

Is there another Earth out there?
Is there life on it?

Requirements for habitability

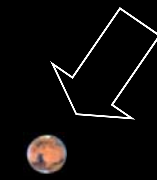
1. Planet size:

~ 0.5 – 2 Earth size

not habitable
(too large, hydrogen gas does not escape)

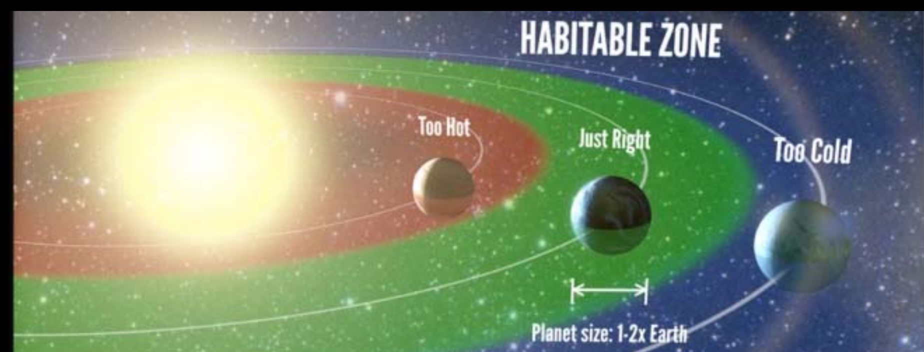
habitable

not habitable
(too small to keep oxygen and water)



2. Temperature:

0-100 C



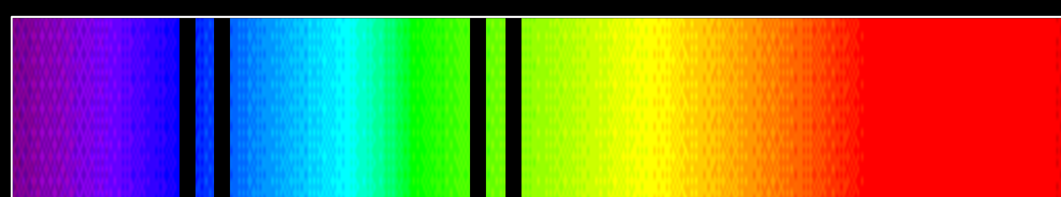
Credit: Petigura/UC Berkeley, Howard/UH-Manoa, Marcy/UC Berkeley

3. Biomarkers:

water and oxygen

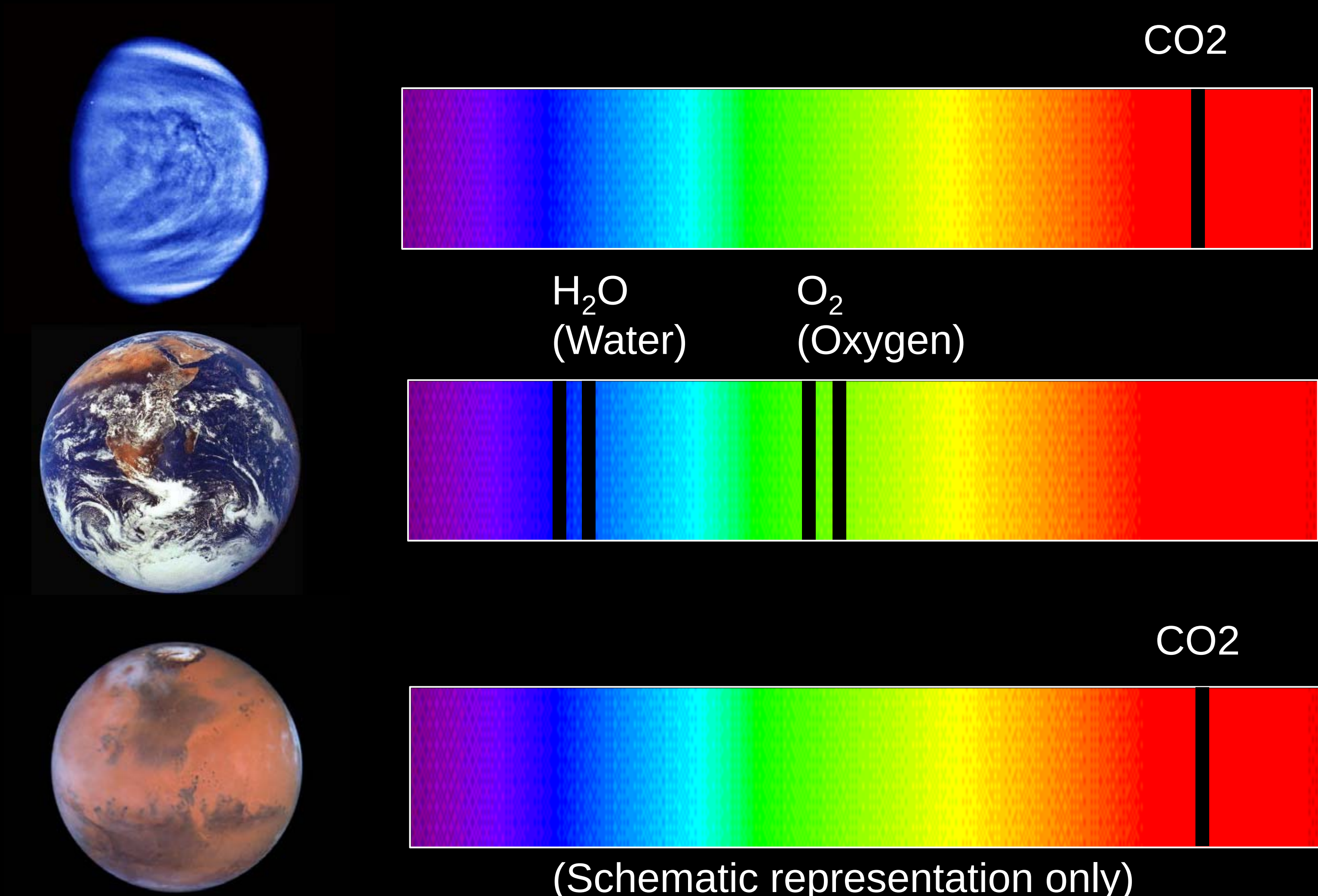
H_2O
(Water)

O_2
(Oxygen)



(Schematic representation only)

Spectroscopy: detecting biomarkers

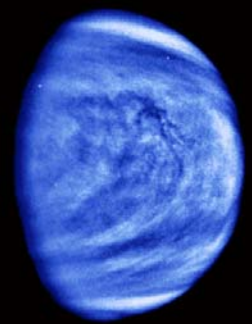


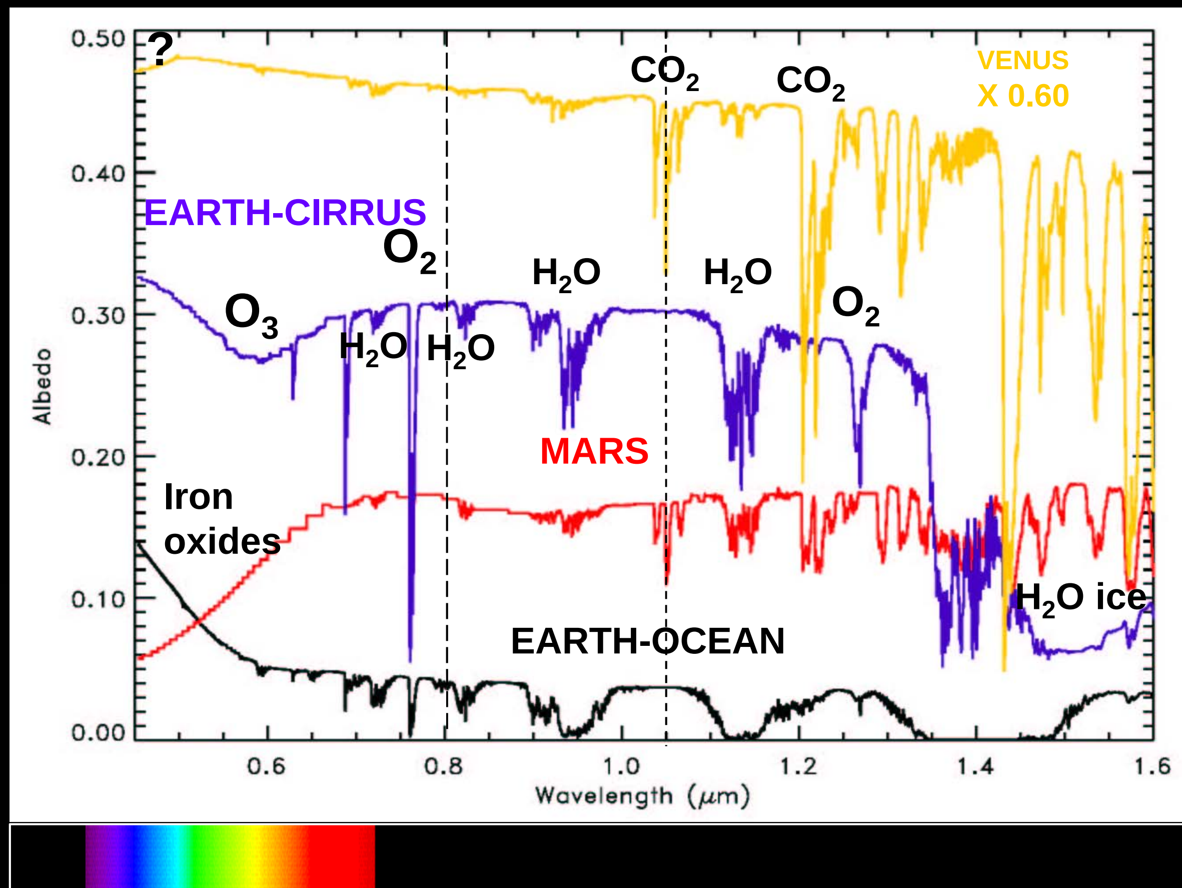
(Schematic representation only)

<u>Detecting atmospheric oxygen and water likely indicates life</u>

(because very few non-biological processes can sustain an oxygen atmosphere)

Spectroscopy: detecting biomarkers





<u>Detecting atmospheric oxygen and water likely indicates life</u>

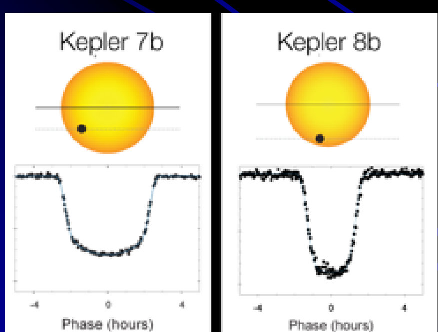
(because very few non-biological processes can sustain an oxygen atmosphere)

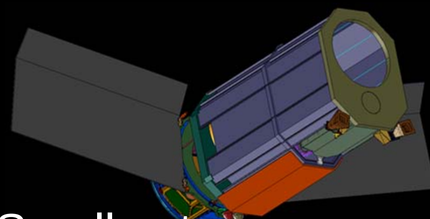
Beyond Kepler: Direct imaging missions

2010 2020 2030

Kepler

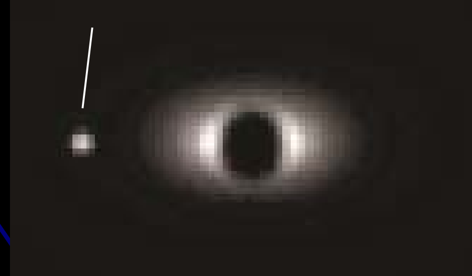
Earth-size
Habitable zone
No spectroscopy (biomarkers)
Not nearby systems





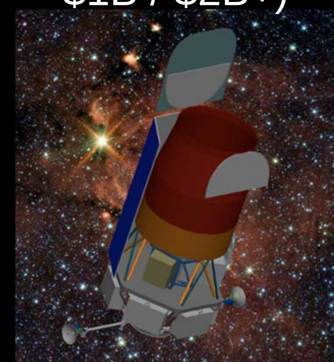
Small sats
(0.25-0.7m,
~$10 – 200M)
Earth-size
Habitable zone
Spectroscopy
Two stars: αCen

Another Earth?



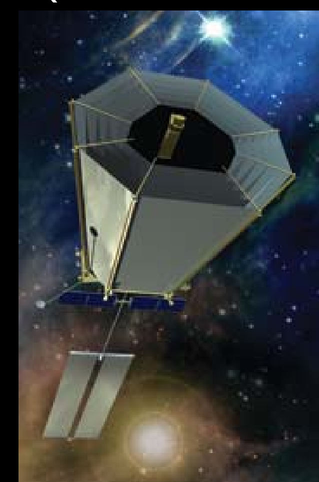
Simulation of an exo-Earth around αCen
with a $1B mission (1.5m telescope)

Exo-C or AFTA
(1.5m / 2.4m,
$1B / $2B+)



Earth-size
Habitable zone
Spectroscopy
~2-6 stars

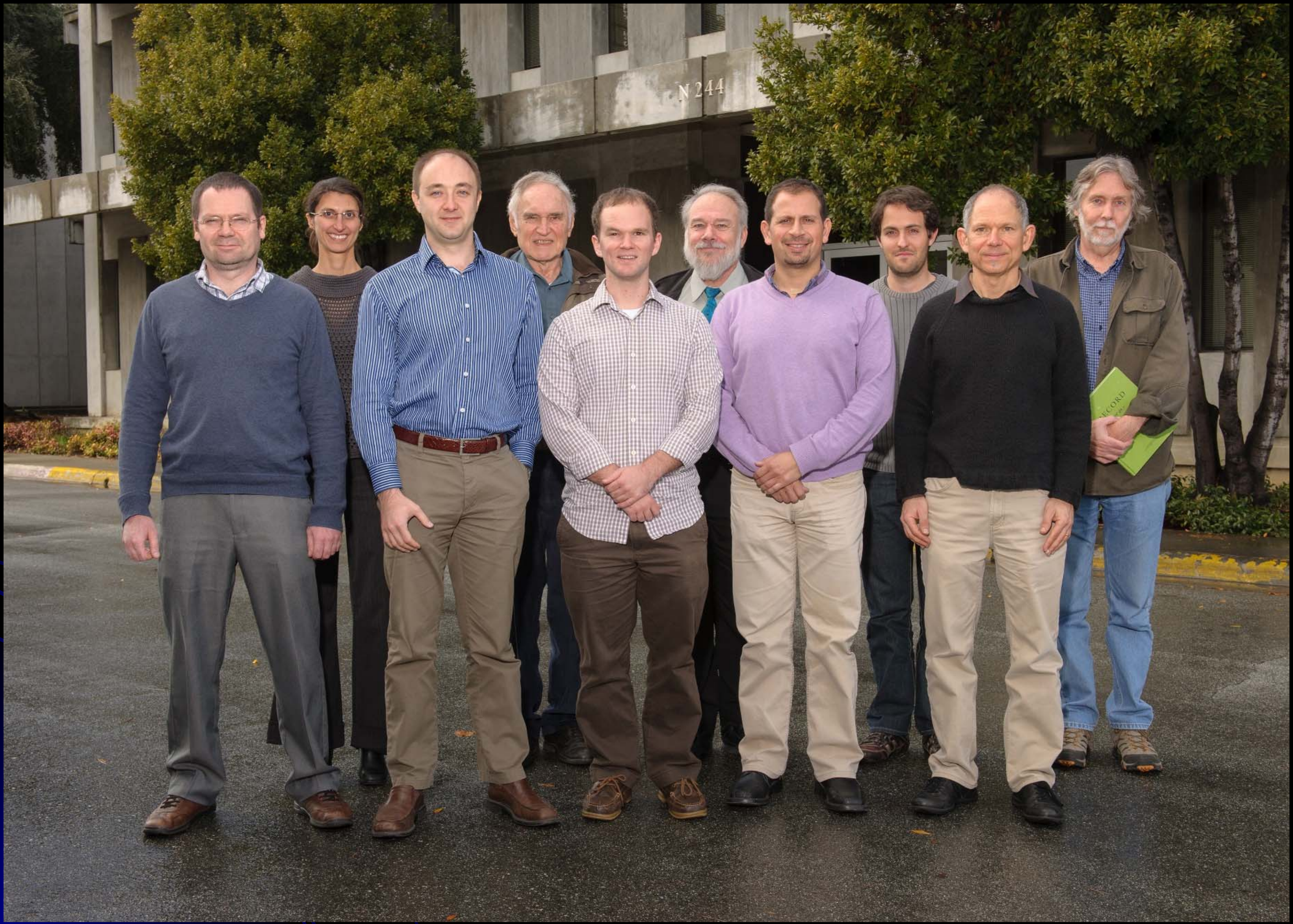
New Worlds
Telescope
($4-8m, $4B+)



Earth-size
Habitable zone
Spectroscopy
~100s of Earths

All these missions also do ground-breaking science on non-habitable planets

The Ames Coronagraph Experiment (ACE)



People and organizations partnering with ACE

NASA ARC
Ruslan Belikov
Thomas Greene
Eugene Pluzhnik
Sandrine Thomas
Fred Witteborn
Dana Lynch
Paul Davis
Eduardo Bendek
Kevin Newman

UofA
Olivier Guyon
Glenn Schneider
Julien Lozi

L3 Tinsley
Jay Daniel
Asfaw Bekele
Lee Dettmann
Bridget Peters
Titus Roff
Clay Sylvester

Princeton
Jeremy Kasdin
Bob Vanderbei
David Spergel
Alexis Carlotti

STScI
Laurent Pueyo

JPL
Brian Kern
Andy Kuhnert
John Trauger
Wes Traub
John Krist
Marie Levine
Stuart Shaklan
K. Balasubramanian

Lockheed Martin
Domenick Tenerelli
Rick Kendrick
Alan Duncan
Wes Irwin
Troy Hix


Stars are a billion times brighter…

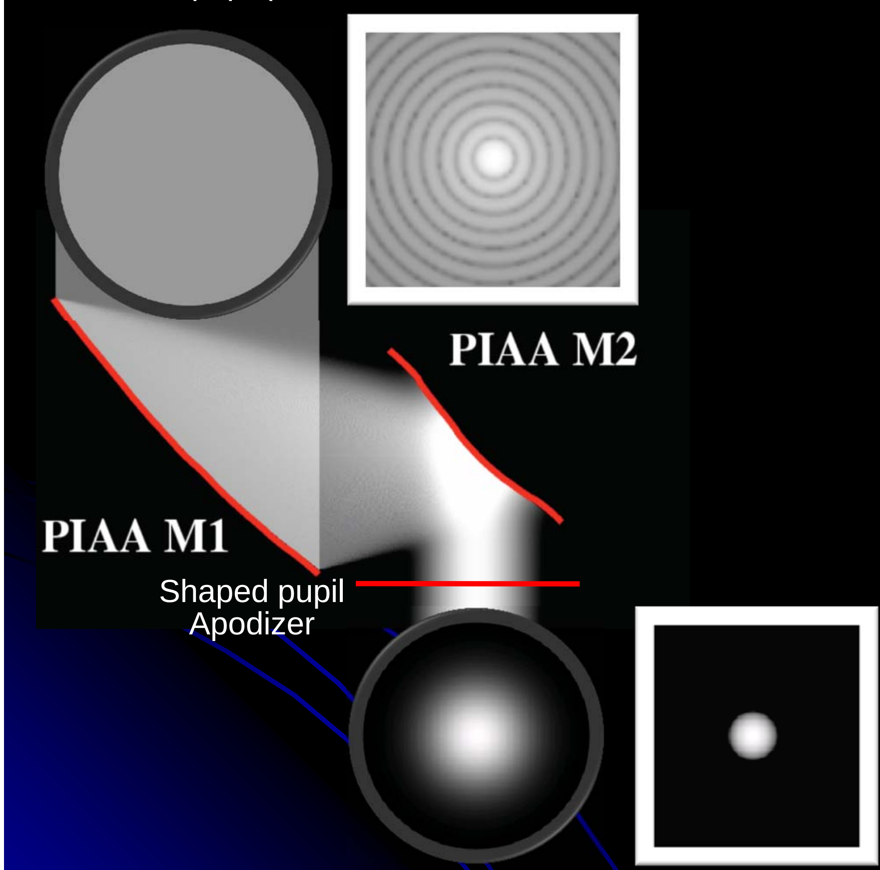

...than the planet
...hidden
in the glare.


Like this firefly.

Blocking the star: the PIAA Coronagraph (phase-induced amplitude apodization)

Original uniformly illuminated pupil plane

Focal plane

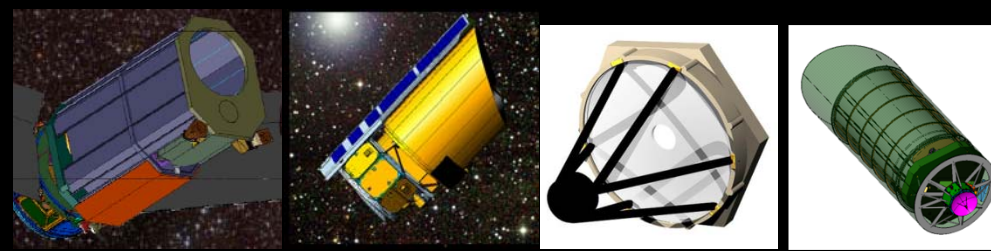


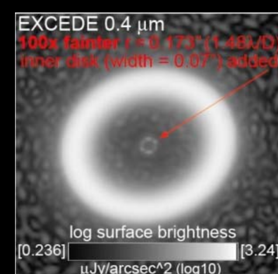
New, apodized pupil plane

Focal plane

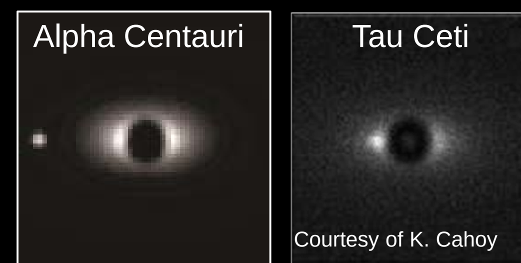
Mission concepts using PIAA

Small Sats (0.25-0.7m) Exo-C (1.4m) AFTA (2.4m) NWO (4m)





HZ disk simulation (small inside disk)



ExoEarth direct image simulations

- PIAA is a powerful technology to block the star in order to reveal planets
- Successful track of technology development at Ames over the past 6 years (as well as at partner institutions)
- One of the potential architectures selected by NASA for the Exo-C and AFTA missions

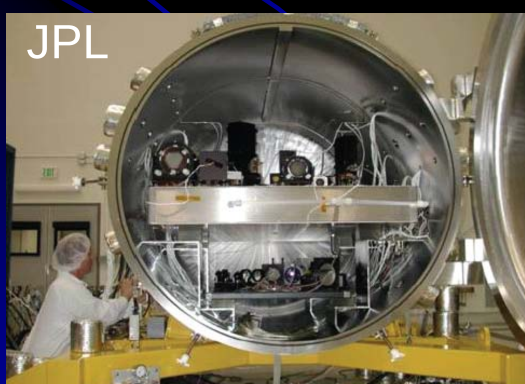
Ruslan Belikov, NASA Ames Coronagraph Laboratory

Testbeds and critical hardware

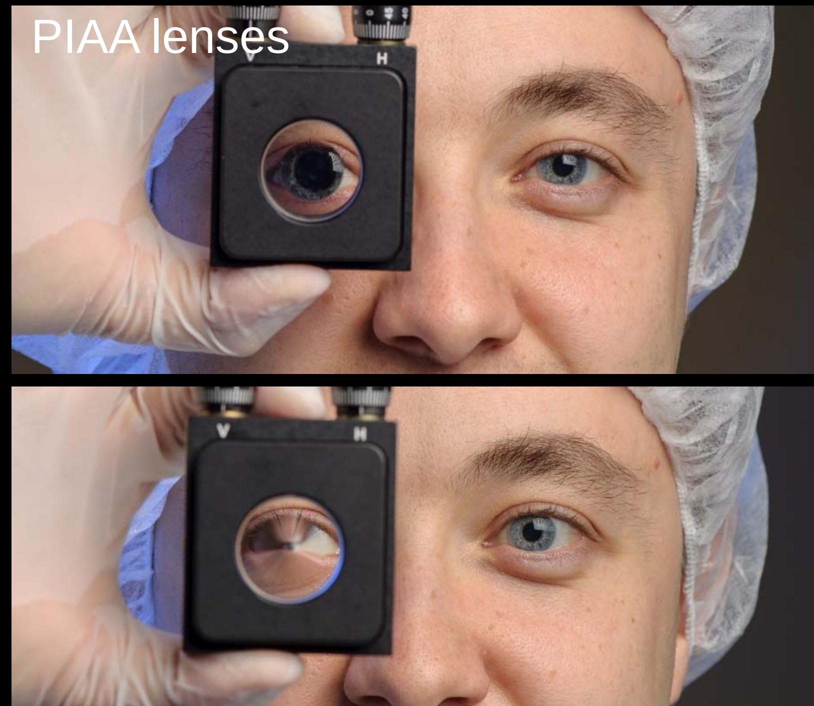
ACE testbed

Lockheed Martin

JPL

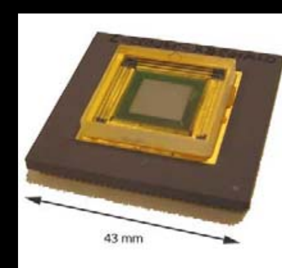


PIAA lenses



PIAA mirrors

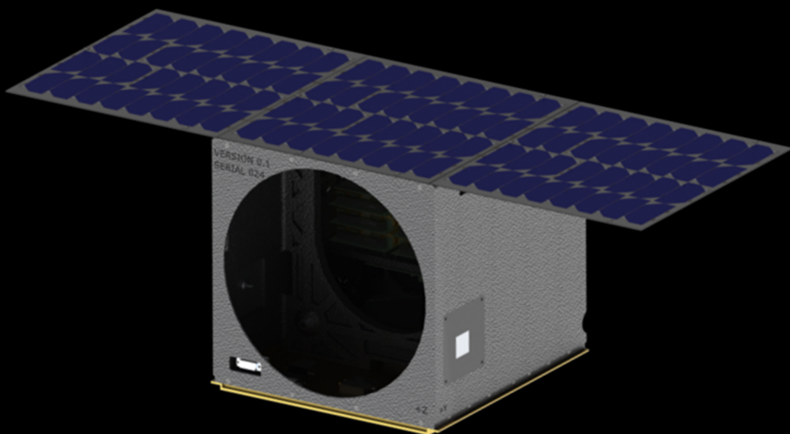
Deformable mirror



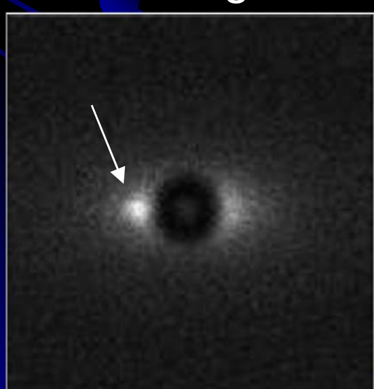
State of the art performance in the lab

Ruslan Belikov, NASA Ames Coronagraph Laboratory

Highligthed effort:
αCen imager



Earth twin image simulation



- Recently started
- 0.25m telescope
- ~$5M (rough estimate)
- Theoretically capable of finding biomarkers on habitable planets around α Centauri (if they exist)

Conclusions

- Technology to find biomarkers and life on other worlds is rapidly maturing
- If there is a habitable planet around the nearest star, we may be able to detect it this decade with a small satellite mission
- In the 2030 decade, we will likely know if there is life in our Galactic neighborhood (~1000 nearest stars)

Earth, as seen by Voyager 1 at a distance of 4 billion miles.